Structures Congress 2017

Bridges and Transportation Structures

Selected Papers from the Structures Congress 2017

Denver, Colorado
April 6–8, 2017

ASCE

EDITED BY
J. G. (Greg) Soules, P.E., S.E., P.Eng

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Preface

The Structures Congress has a robust technical program focusing on topics important to Structural Engineers.

The papers in the proceeding are organized in 4 volumes

Volume 1 includes papers on Blast and Impact Loading and Response of Structures
Volume 2 includes papers on Bridges and Transportation Structures
Volume 3 includes papers on Buildings and Nonbuilding and Special Structures
Volume 4 includes papers on Other Structural Engineering Topics including; Business and Professional Practice, Natural Disasters, Nonstructural Systems and Components, Education, Research, and Forensics

Acknowledgments

Preparation for the Structures Congress required significant time and effort from the members of the National Technical Program Committee, the Local Planning Committee. Much of the success of the conference reflects the dedication and hard work by these volunteers.

We would like to thank GEICO and Pearl for Sponsoring the Congress proceedings and supporting the Structures Congress in such a generous way.

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The Joint Program Committee would like to acknowledge the critical support of the sponsors, exhibitors, presenters, and moderators who contributed to the success of the conference through their participation.

On behalf of our dedicated volunteers and staff, we would like to thank you for spending your valuable time attending the Structures Congress. It is our hope that you and your colleagues will benefit greatly from the information provided, learn things you can implement and make professional connections that last for years.

Sincerely,

J. Greg Soules, P.E., S.E., P.Eng, SECB, F.SEI, F.ASCE

Contents

Bridges and Transportation Structures

Evaluation of Bond Strength for AFRP Reinforcing Bars in Columns with Self-Consolidating Concrete

Emmanuel Chinaka[1]; Mehdi Shokouhian[2]; Steve Efe[3]; and Monique Head[4]

[1]CBEIS 232, Dept. of Civil Engineering, Morgan State Univ., 1700 E. Cold Spring Ln., Baltimore, MD 21251. E-mail: emchi1@morgan.edu
[2]CBEIS 205, Dept. of Civil Engineering, Morgan State Univ., 1700 E. Cold Spring Ln., Baltimore, MD 21251. E-mail: mehdi.shokouhian@morgan.edu
[3]CBEIS 233, Dept. of Civil Engineering, Morgan State Univ., 1700 E. Cold Spring Ln., Baltimore, MD 21251. E-mail: steve.efe@morgan.edu
[4]CBEIS 209, Dept. of Civil Engineering, Morgan State Univ., 1700 E. Cold Spring Ln., Baltimore, MD 21251. E-mail: monique.head@morgan.edu

Abstract
Previous research and design codes have focused on developing equations, mostly empirical based on experimental studies, to determine the bond strength of steel bars with different types of concrete. However, limited studies have been conducted on FRP bars particularly embedded in Self-Consolidating Concrete (SCC), but very few using Aramid Fiber Reinforced Polymers (AFRP) bars. This investigation aims to study the influence of two main parameters: 1) superplasticizer dosage and 2) water to cement ratio on the bond strength and bond slip model of the AFRP bars and SCC. Results show a significant effect of superplasticizer on the bond strength of AFRP bars embedded within SCC. Moreover, the effect of the w/c ratio is quantified and its correlation with bond strength is presented. The slippage of the AFRP bars embedded in the concrete was accurately measured to determine a precise bond-slip model that is compared to conventional concrete performance.

1. Introduction
SCC is a type of concrete that was developed and introduced in Japan in the late 1980s by Professor Hajime Okamura (Zia, et al., 2005). SCC has the ability to flow using its self-weight without the need for vibration. This idea and concept were motivated by the lack of workers needed for construction. In the 1990s, the United States began implementing SCC for infrastructure. In North America and other places in the world, SCC has been used for substructure repair such as bridge repair. The annual cost of concrete repairs in North America is about $20 billion, and a significant amount of the money is spent on bridge substructure repairs (Orangun, et al., 1977). The use of SCC is becoming more widespread due to its high flow ability and durability. The use of SCC allows for a reduction in labor and mechanical vibration, and better construction environment due to the elimination of the noise. Studies have been conducted to understand the movement and flow of SCC, while also understanding the components that will affect it. The reduction of labor costs, better self-leveling, and elimination of consolidation noise on job sites is a major reason why the use of SCC is widely growing in precast construction (Ghafoori, et al., (2014)- (Kassimi, et al., 2014). A great amount of research and understanding must go into SCC, considering the benefits that are associated with it in order to attain full potential of this material (Gibb, et al., 2012). The main additive in SCC, which makes it self-consolidating is superplasticizer (SP). This additive allows a reduction in the water to cement ratio of the concrete that in return will increase the compressive strength, and allow for

great workability of the concrete. Given the demand to use corrosion-resistant bars in the reinforced concrete members, coupled with the advantages of SCC, this research explores the bond strength of aramid fiber reinforced polymer (AFRP) bars when used in conjunction with SCC. In addition to further understanding the bond behavior of the bar and the concrete during loading, a bond slip model can display the movement and actual bonding of the bar and concrete. Perfect bonding is something that is assumed in most numerical studies of FRP reinforced concrete structures which results in non-realistic and imprecise predictions of the behavior of the structure (Lin & Zhang, 2013). Giving that the amount of data on the bond slip of FRP bars and SCC is limited, it is important that data is acquired in order to obtain an understanding and to ensure adequate bonding behavior. As previously stated, there is a lack of experimental data to express the bonding behavior between SCC and the AFRP bars for structural concrete design. Therefore, this study will provide more data concerning this concept through a series of pullout tests using AFRP bars in SCC to understand the effects of the superplasticizer and water cement ratio on the bond strength and bond slip model.

2. Previous research

Separately research on bond behavior of FRP bars and SCC is a topic which is becoming more frequent, but information of AFRP bars embedded in SCC is very limited. Research was done to show the effects of superplasticizer on the steel-concrete bond strength, (Brettmann, et al., 1986). Several different variables were taken into account in this research. The degree of consolidation and the slump of the concrete were key variables within this research. In addition, the concrete temperature and the placement of the bars were investigated as well. Result showed that high slump concrete had a higher bond strength than the concrete with low slump. Results showed that vibration on the concrete had a positive effect on the bond strength of the FRP bars and the concrete.

Testing was conducted where steel and GFRP bars were studied to show how bleeding, statistical and dynamical segregation had an effect on the bond between the bars and SCC. The bond behavior of SCC was compared to that of normal concrete (Golafshani, et al., 2014). The results given by this test showed that the bond behavior for suitable adhesion treatment of steel bars is higher than that of GFRP bars. As well, reducing the water to cement ratio and substituting it with a high powder material decreases the bond strength variations.

Data shows that AFRP bars have a higher tensile strength, elastic modulus and ultimate strain compared to that of other FRP bars. From the AFRP bars that were tested, results showed that it had a bond strength ranging from 1724–2537 MPa, elastic modulus ranging from 41–125 GPa and an ultimate strain ranging from 1.9-4.4%. These values obtain are shown to be much greater than that of Glass fiber reinforcing polymers (GFRP) bars (Kocaoz, et al., 2015).

Research was performed that further looked into the bond behavior of AFRP and CFRP (Aramid and Carbon) bars and normal concrete, (Lee, et al., 2013). This research aims to investigate how the physical characteristic such as the bar diameter and the embedment length of the AFRP and CFRP bar effect the bond behavior. This research states that an increase in embedment length and bar diameter have negative effect on the bond strength of the bar and the concrete.

Data on the bond slip of AFRP bars is something that is very limited and rare compared to that of steel bars. 30 pullout tests on GFRP bars and normal strength concrete were performed (Tastani, et al., 2005). The bar roughness and the diameter of the bar were parameter considered inside of this experiment. Results showed that the bond slip curve had a stiffer response with a lower bond stress with the smoother bar surfaces.